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(54) **COILED TUBING INJECTOR WITH REACTIVE CHAIN TENSION**

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E21B 19/10 (2006.01)

(52) **U.S. Cl.**
CPC ***E21B 19/22*** (2013.01); ***E21B 19/10*** (2013.01)

(58) **Field of Classification Search**
CPC E21B 19/22
See application file for complete search history.

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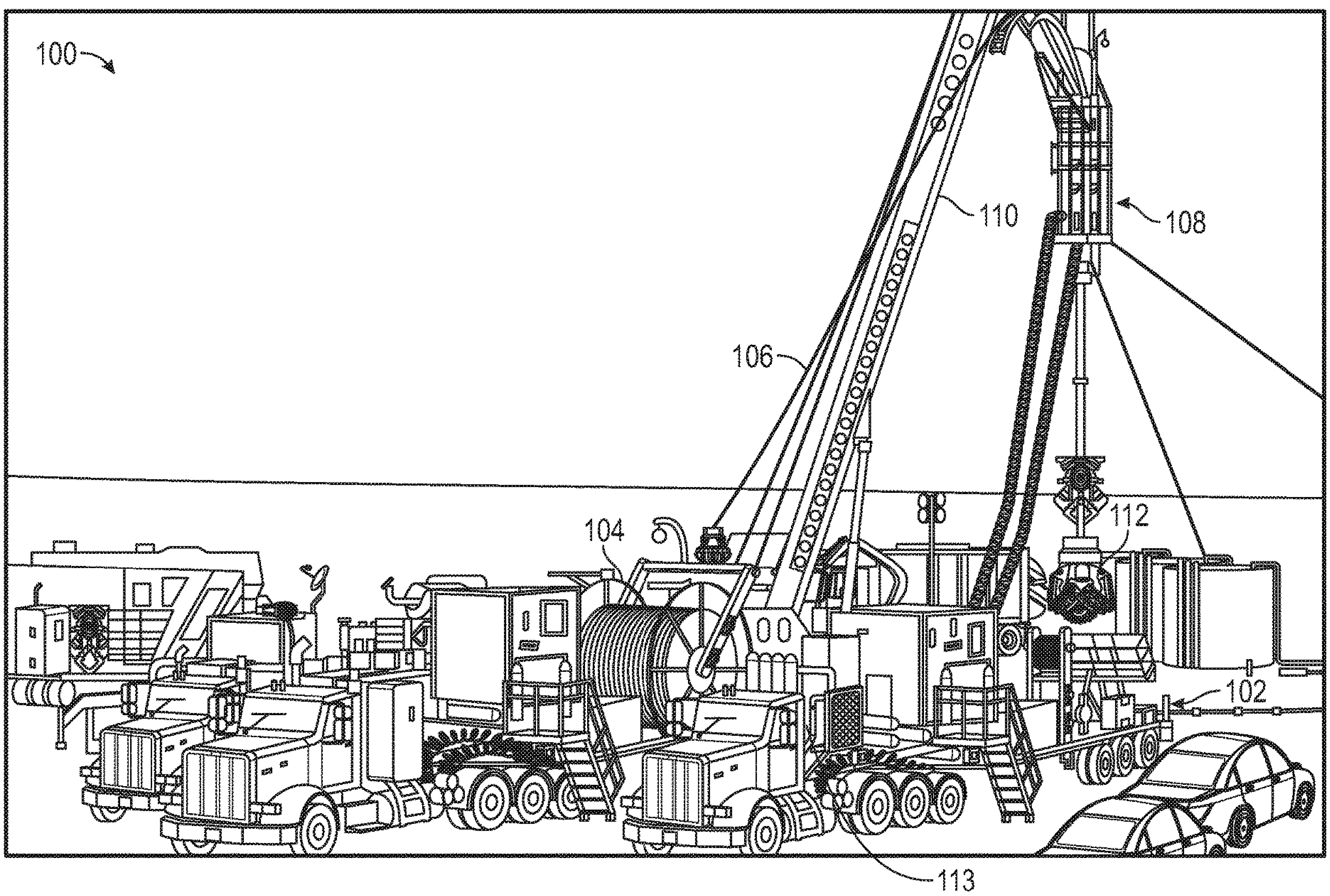
(57) **ABSTRACT**

A coiled tubing injector including two or more drive chains each carrying a plurality of grippers for engaging coiled tubing within a grip zone defined between the two or more drive chains, a drive system including at least one hydraulic motor connected to a drive line and a return line forming a drive circuit for fluidly powering the at least one hydraulic motor, and a tension system including at least one hydraulic cylinder for tensioning the two or more drive chains. The tension system can include a reactive chain tension circuit for automatically tensioning the two or more drive chains by maintaining a pressure differential between a fluid pressure within the drive line and a fluid pressure within the at least one hydraulic cylinder.

20 Claims, 7 Drawing Sheets



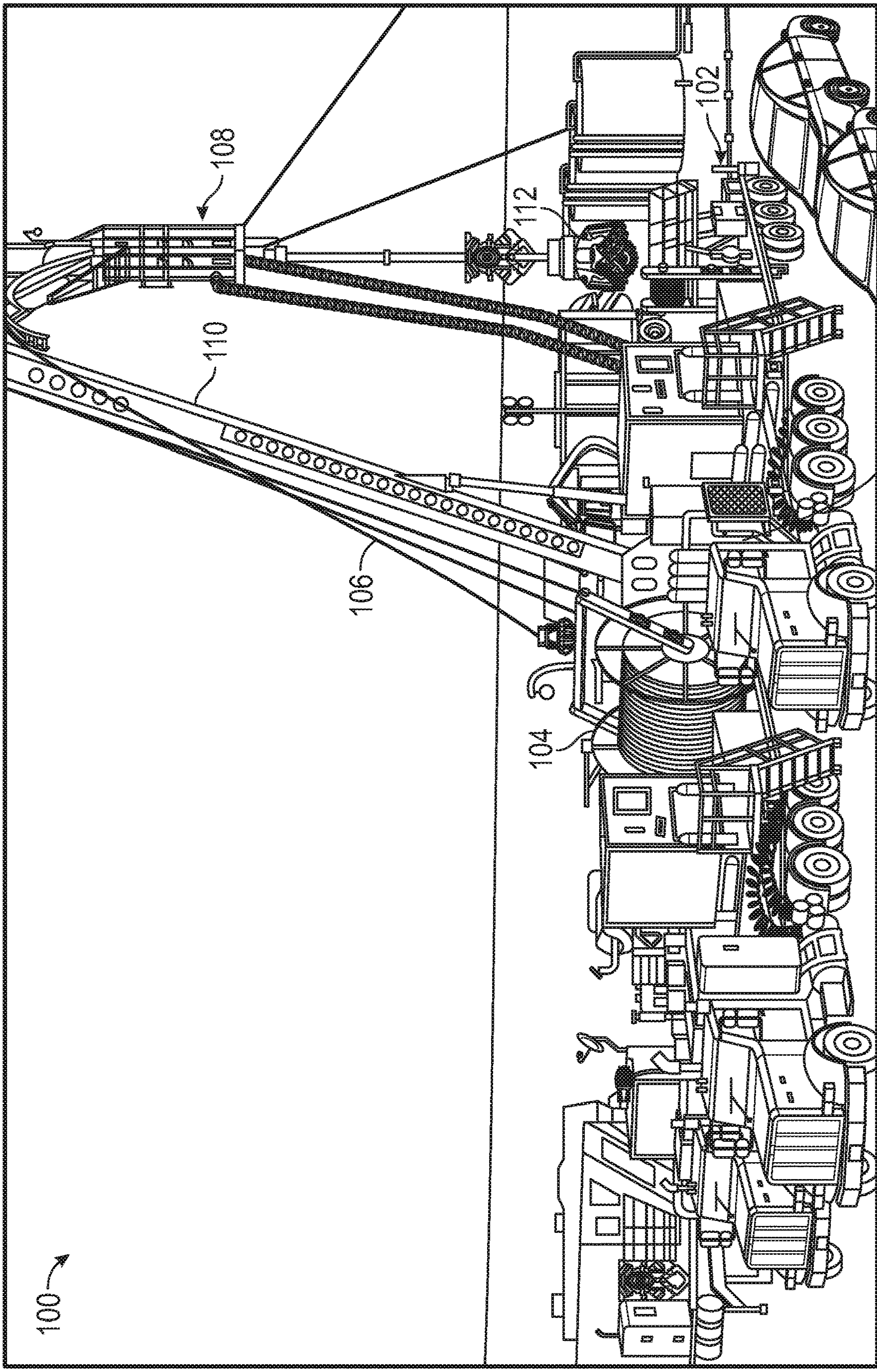


FIG. 1

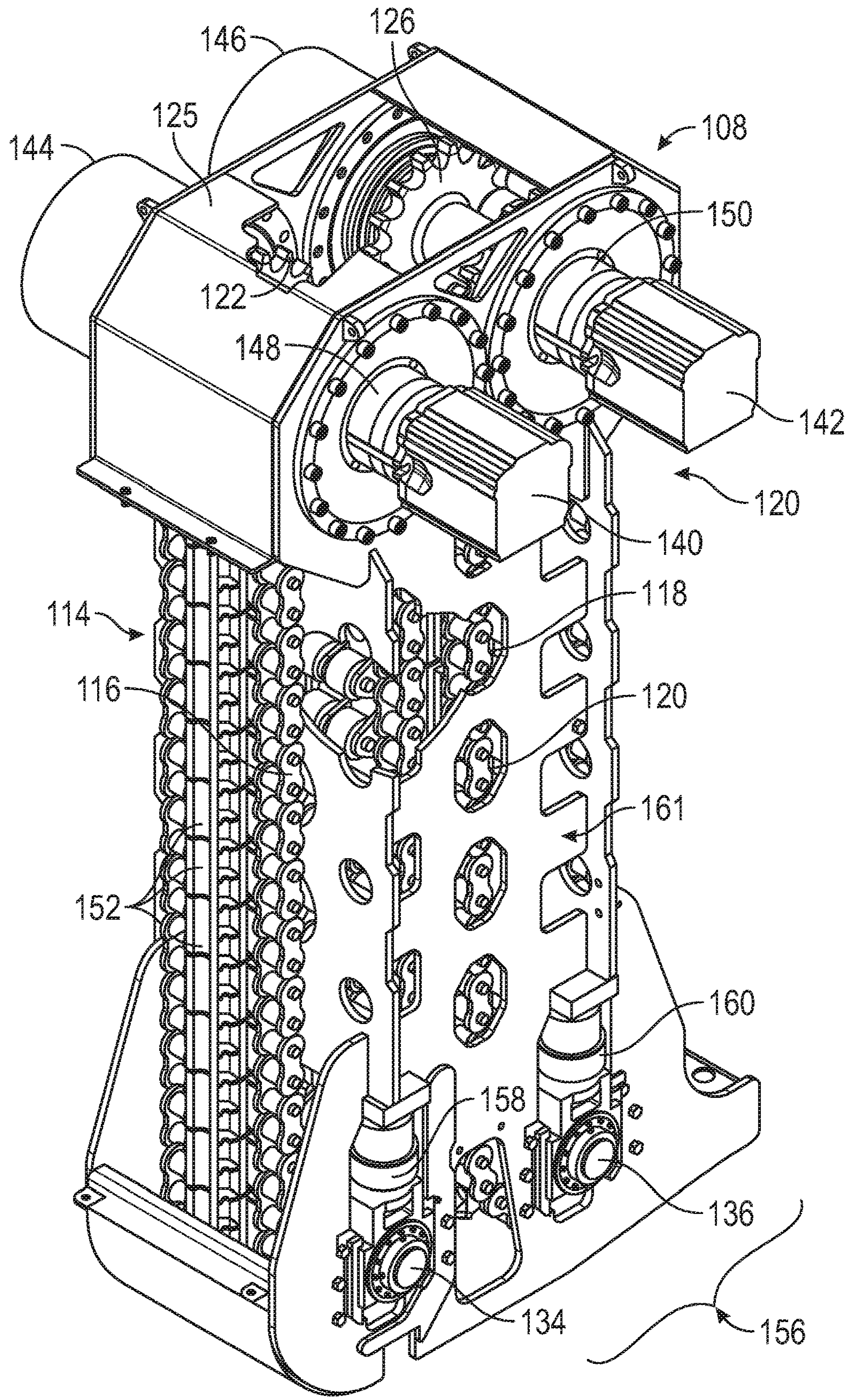

126
146
125
144
108
150
122
148
142
120
140
118
114
116
120
161
152
160
158
136
134
156

FIG. 2

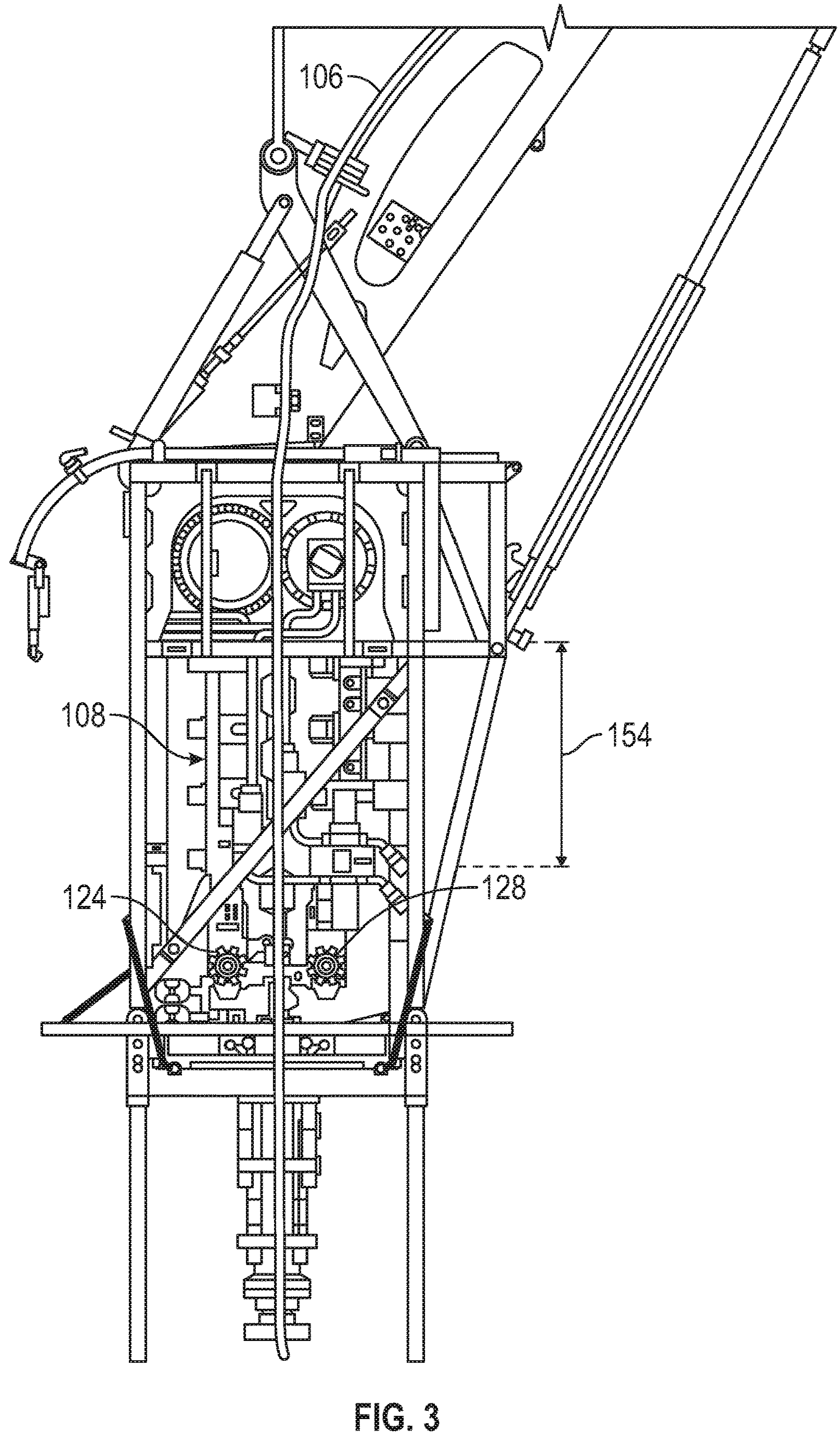


FIG. 3

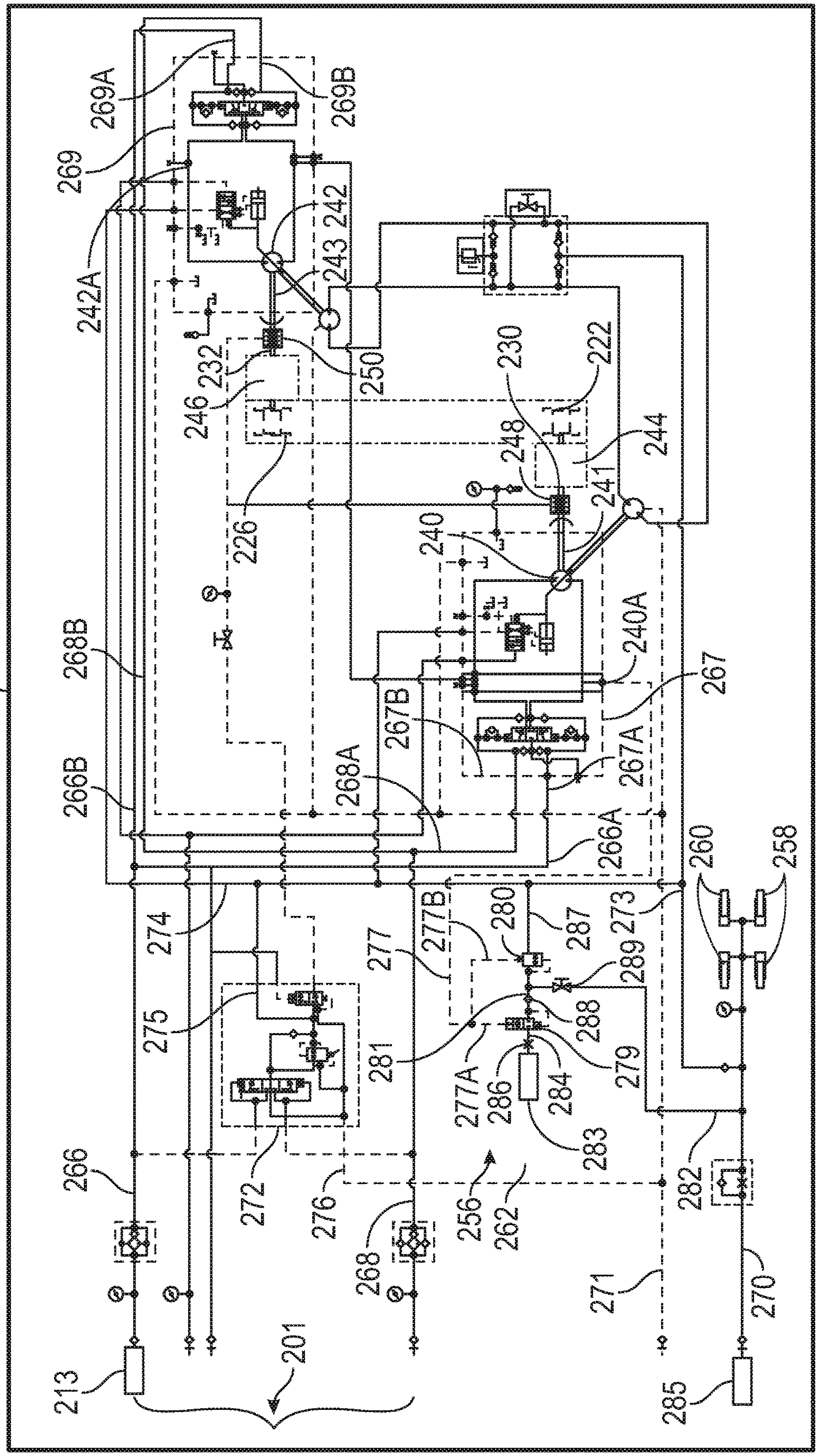

200
269A
269B
269
242A
242
243
232
250
246
226
230
222
248
244
241
240
240A
268B
266B
268A
267B
267
267A
266A
274
275
277
277B
280
287
273
260
258
289
288
281
279
277A
286
284
283
282
272
266
276
268
256
262
271
270
213
201
285

FIG. 4

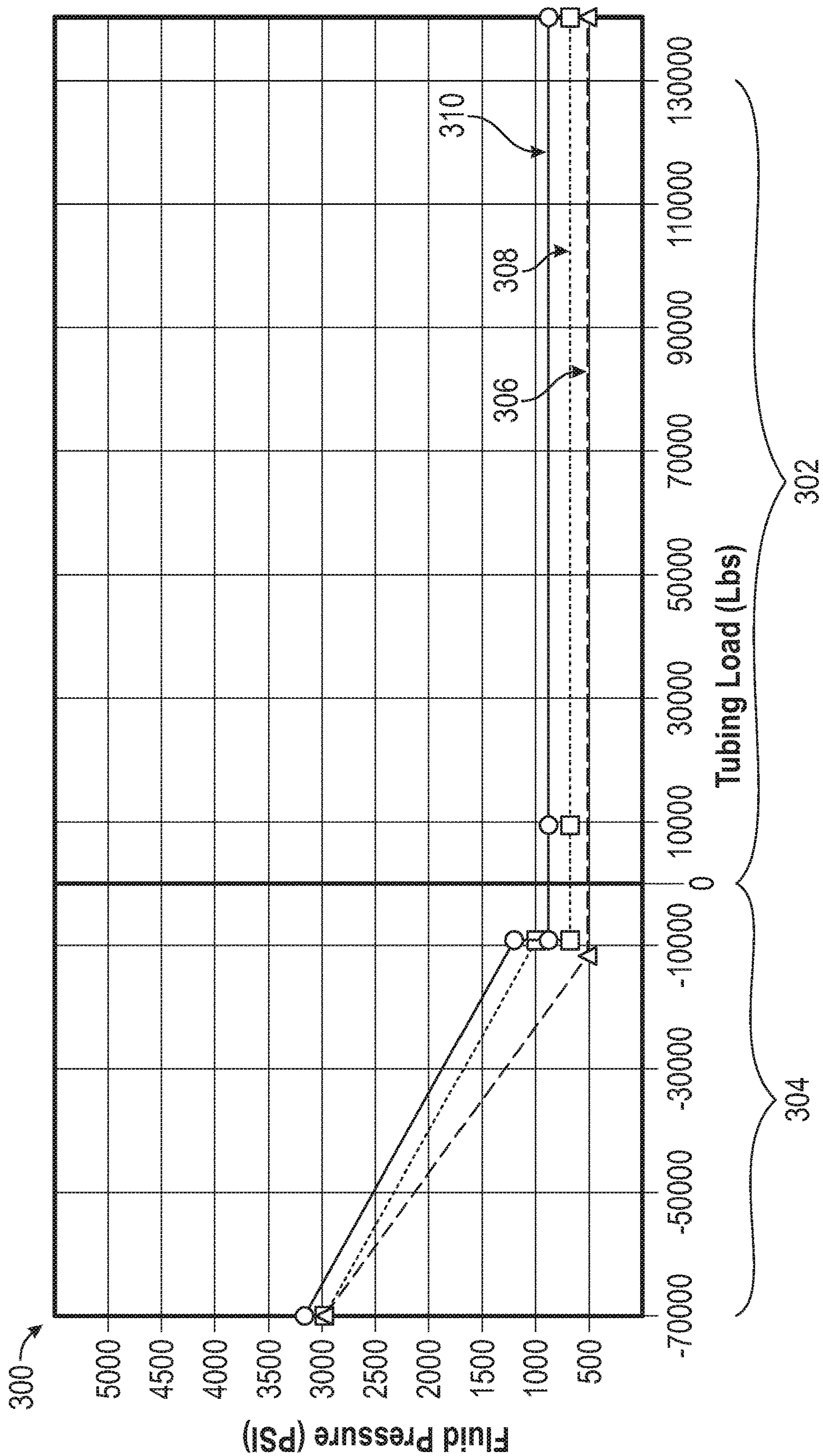

300
Fluid Pressure (PSI)
5000
4500
4000
3500
3000
2500
2000
1500
1000
500
Tubing Load (Lbs)
-70000
-50000
-30000
-10000
0
10000
30000
50000
70000
90000
110000
130000
302
304
306
308
310

FIG. 5

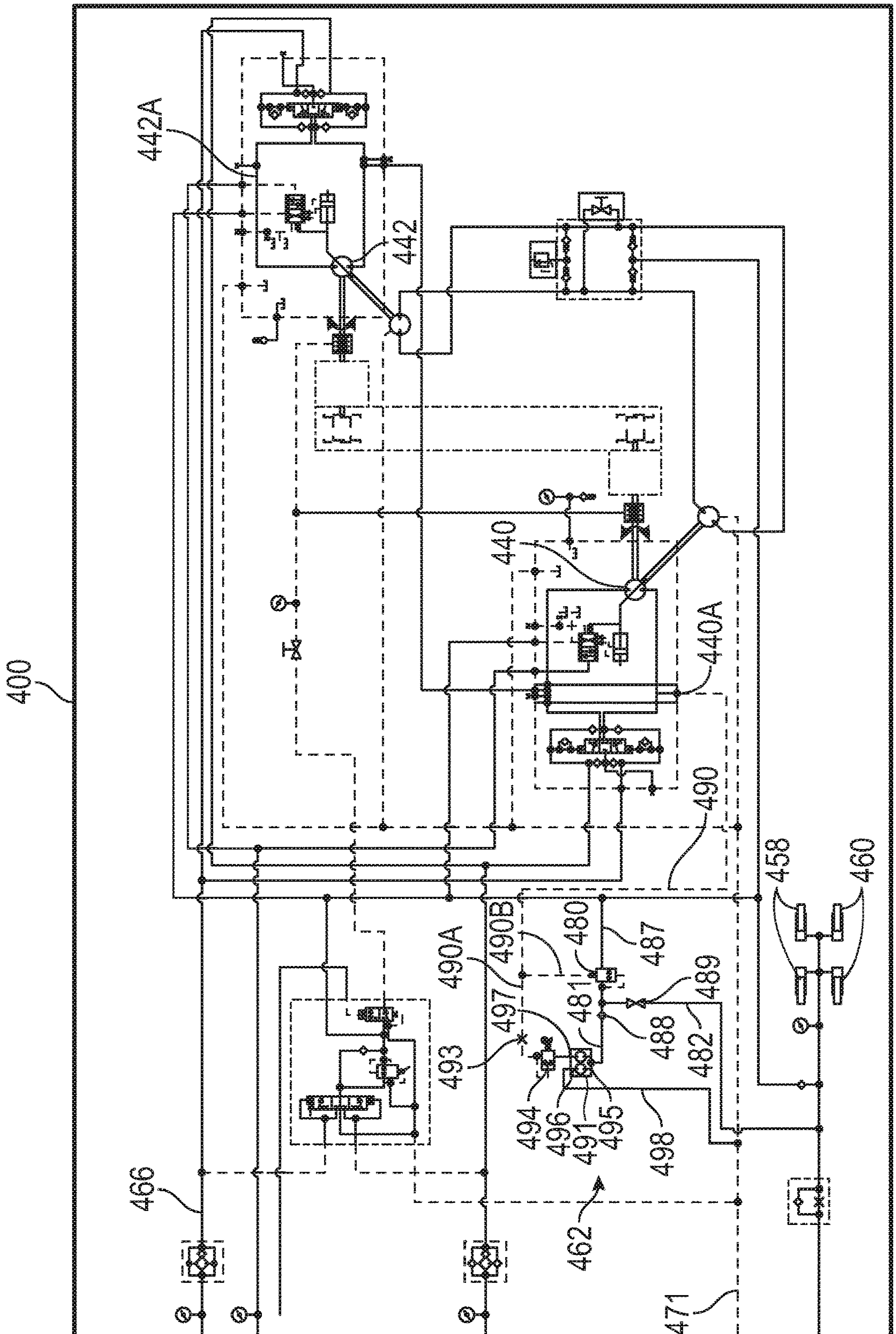

400
442A
442
440
440A
490
458
460
490A
490B
480
487
497
481
489
488
482
493
494
496
491
495
498
466
462
471

FIG. 6

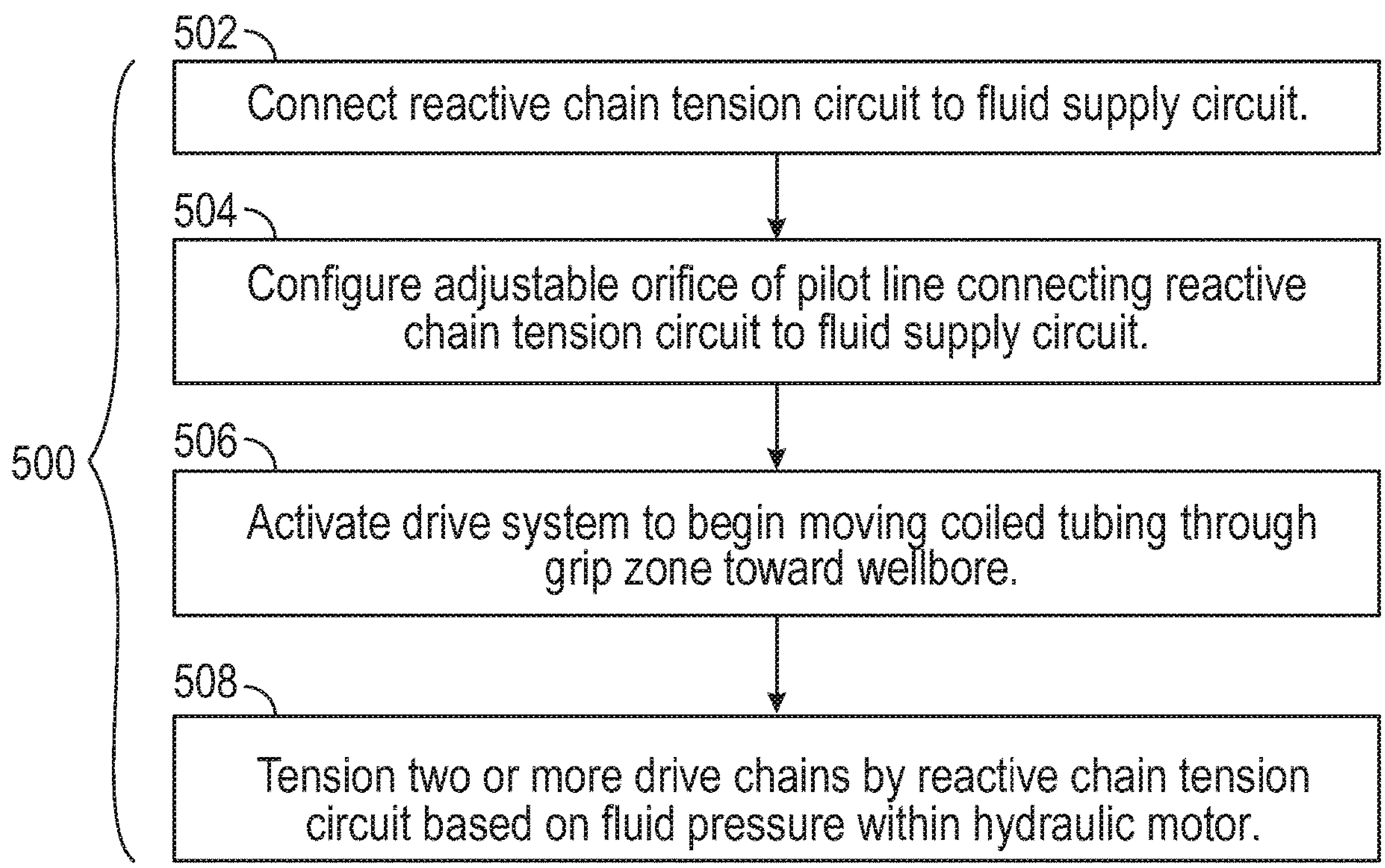

502
Connect reactive chain tension circuit to fluid supply circuit.
504
Configure adjustable orifice of pilot line connecting reactive chain tension circuit to fluid supply circuit.
506
Activate drive system to begin moving coiled tubing through grip zone toward wellbore.
508
Tension two or more drive chains by reactive chain tension circuit based on fluid pressure within hydraulic motor.
500

FIG. 7

COILED TUBING INJECTOR WITH REACTIVE CHAIN TENSION

TECHNICAL FIELD

The present disclosure pertains generally, but not by way of limitation, to coiled tubing injectors for driving continuous tubing into well bores. More particularly, but not by way of limitation, the present disclosure pertains to systems and methods for tensioning drive chains within coiled tubing injectors.

BACKGROUND

The background description provided herein is for the purpose of generally presenting the context of the disclosure. Work of the presently named inventors, to the extent it is described in this background section, as well as aspects of the description that may not otherwise qualify as prior art at the time of filing, are neither expressly nor impliedly admitted as prior art against the present disclosure.

Coiled tubing refers generally to continuous tubing coiled on a reel or spool. Coiled tubing is significantly faster, relative to conventional interconnected rigid piping, to trip into wellbores or trip out of wellbores. Additionally, coiled tubing can function as either temporary or permanent piping in production wells. As such, coiled tubing is commonly used in both drilling and workover operations at well sites. Coiled tubing injectors are devices for inserting coiled tubing into, and withdrawing coiled tubing from, wellbores. When in use, coiled tubing injectors are typically situated directly above a wellbore; and can position the coiled tubing within the wellbore by precisely controlling the rate at which the coiled tubing moves through die coiled tubing injector. For example, many coiled tubing injectors include a pair of counter-rotating drive chains each carrying grippers which continuously engage the coiled tubing within a "grip-zone" (e.g., an area in which the grippers are in contact with the coiled tubing) defined between the drive chains.

The drive chains are often rotated by one or more hydraulic motors fluidly powered by an external power unit, such as a hydraulic power pack. While tripping the coiled tubing into a wellbore, the coiled tubing is generally in a "pipe-heavy" state, in that the downward force of gravity acting on the coiled tubing is greater than any upward force acting on the coiled tubing. When the coiled tubing is pipe-heavy, the coiled tubing injector can function to control the rate at which the coiled tubing passes through the grip zone by resisting the downward force of gravity acting on the coiled tubing. As can be appreciated, a portion of each drive chain within the grip zone will be placed under constant tension when the grippers begin supporting the weight of the coiled tubing. While tripping the coiled tubing into a wellbore, the coiled tubing may switch from a pipe-heavy state to a pipe-light state, in that the downward force of gravity acting on the coiled tubing is less than an upward force acting on the coiled tubing caused by pressure within a wellbore. For example, the coiled tubing can switch from a pipe-heavy state to a pipe-light state, such as due to an obstruction located within the wellbore, internal pressure within the wellbore, or other factors.

When the coiled tubing becomes pipe-light, such as in response to an obstruction or internal pressure within the wellbore, the coiled tubing injector must function to push the coiled tubing into the wellbore by applying a downward, or "snubbing", force sufficient to overcome the pressure within the wellbore. However, such an upward force will act on the coiled tubing injector in a direction opposite to the downward movement of the grippers carried by the drive chains. As can be appreciated, this can cause a portion of each drive chain passing through the grip zone to lose tension and rapidly become slack or "bunch up", such as in an area near the drive sprockets responsible for supporting and turning the drive chains. Chain bunching can cause serious damage to the coiled tubing, the drive chains, the driven sprockets, the grippers, or other components of the coiled tubing injector. Such damage can be costly to repair, and the downtime associated with repair or replacement of the coiled tubing injector can significantly lengthen a well drilling or workover operation.

To help avoid the above issues, coiled tubing injectors often include a chain tension system operable to adjustably tension the drive chains. For example, a user can increase tension within the drive chains from a preset level to a predetermined level above the preset level if the coiled tubing switches from a pipe-heavy state to a pipe-light state, such as to prevent the drive chains from becoming vulnerable to chain bunching. Subsequently, if the tubing switches back to a pipe-heavy state, the user can proportionally reduce the tension within the drive chains. However, existing chain tension systems require a user to closely monitor a tubing load on the coiled tubing injector, such as to proactively predict necessary tension within the drive chains. The tubing load can be a positive load (e.g., the downward force applied to the injector by the coiled tubing) or a negative load (e.g., the upward force applied to the injector by the coiled tubing); and can change frequently during continuous operation of the coiled tubing injector. For example, if the coiled tubing encounters an obstruction within a wellbore, the tubing load can rapidly and unexpectedly switch from a positive load to a negative load.

As such, existing chain tension systems are susceptible to user error. For example, a user can fail to notice that a negative tubing load has arisen, such as indicating the coiled tubing has switched from a pipe-heavy state to pipe-light state; and will therefore also fail to proportionally increase the tension in the drive chains. As a result, the drive chains are likely to begin bunching. Similarly, a user can fail to notice that a positive tubing load has arisen, such as indicating that the coiled tubing has switched back from a pipe-light state to a pipe-heavy state; and will therefore also fail to proportionally decrease the tension in the drive chains. As a result, the drive chains, the drive sprockets, chain guides, and many other components of the coiled tubing injector are likely to prematurely degrade due to excessive and unnecessary tension present within the drive chains. For example, when the drive chains are tensioned for pipe-light operating conditions, outer-facing portions of the drive sprockets, and outer facing portions of idler sprockets helping to guide or support the drive chains, can be under a significant tension force.

SUMMARY

In a non-limiting example, a coiled tubing injector can include: two or more drive chains each forming a continuous loop and carrying a plurality of grippers for engaging coiled tubing within a grip zone defined between the two or more drive chains: a drive system including: a first drive sprocket engaged with a first drive chain of the two or more drive chains; a second drive sprocket engaged with a second drive chain of the two or more drive chains; at least one hydraulic motor for turning the first drive sprocket and the second drive sprocket, the at least one hydraulic motor connected to

a drive line and a return line forming a drive circuit for fluidly powering the at least one hydraulic motor; and a tension system including: at least one hydraulic cylinder for tensioning the two or more drive chains; and a reactive chain tension circuit for automatically tensioning the two or more drive chains by maintaining a pressure differential between a fluid pressure within the drive line and a fluid pressure within the at least one hydraulic cylinder.

In another non-limiting example, a coiled tubing injector can include: two or more drive chains each forming a continuous loop and carrying a plurality of grippers for engaging coiled tubing within a grip zone defined between the two or more drive chains; a drive system including: a first drive sprocket engaged with a first drive chain of the two or more drive chains; a second drive sprocket engaged with a second drive chain of the two or more drive chains; a first hydraulic motor for turning the first drive sprocket; a second hydraulic motor for turning the second drive sprocket, wherein the first hydraulic motor and the second hydraulic motor are connected in parallel to a drive line and a return line forming a drive circuit for fluidly powering the first hydraulic motor and the second hydraulic motor; and a tension system including: one or more first hydraulic cylinders for tensioning the first drive chain, a second hydraulic cylinder for tensioning the second drive chain; and a reactive chain tension circuit for automatically tensioning the first drive chain and the second drive chain by maintaining a pressure differential between a fluid pressure within the drive line and a fluid pressure within the one or more first hydraulic cylinders and the one or more second hydraulic cylinders, wherein the reactive chain tension circuit is connected to a first port of the first hydraulic motor via a pilot line to provide the reactive chain tension circuit with a pressure signal indicative of a tubing load on the coiled tubing injector.

In an additional example, a method of using a coiled tubing injector including two or more drive chains carrying a plurality of grippers for engaging coiled tubing within a grip zone defined between a first drive chain and a second drive chain, and a drive system for turning the two or more drive chains and including at least one hydraulic motor connected to a drive line for fluidly powering the at least one hydraulic motor, can include activating the drive system to begin moving the coiled tubing through the grip zone toward a wellbore; and tensioning the two or more drive chains by a reactive chain tension circuit based on a fluid pressure within the at least one hydraulic motor, by maintaining a pressure differential between the fluid pressure within the at least one hydraulic motor and a fluid pressure within at least one hydraulic cylinder for tensioning the first drive chain and the second drive chain.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** illustrates a perspective view of a coiled tubing unit in place on a well pad, according to one or more examples.

FIG. **2** illustrates an isometric view of the coiled tubing injector of FIG. **1**, according to one or examples.

FIG. **3** illustrates a side view of the coiled tubing injector of FIGS. **1-2**, according to one or more examples.

FIG. **4** illustrates a hydraulic circuit of the coiled tubing injector of FIGS. **1-3** including an example reactive chain tension circuit, according to one or more examples.

FIG. **5** illustrates an example graph illustrating fluid pressure with the reactive chain tension circuit of FIG. **4** as a function of tubing load on the coiled tubing injector of FIGS. **1-3**, according to one or more examples.

FIG. **6** illustrates a hydraulic circuit of a coiled tubing injector of the coiled tubing injector of FIGS. **1-3** including an example reactive chain tension circuit, according to one or more examples.

FIG. **7** illustrates a method of using a coiled tubing injector, according to one or more examples.

In the drawings, which are not necessarily drawn to scale, like numerals may describe similar components in different views. Like numerals having different letter suffixes may represent different instances of similar components. The drawings illustrate generally, by way of example, but not by way of limitation, various embodiments discussed in the present document.

DETAILED DESCRIPTION

The coiled tubing injector of the present disclosure can help to address the above issues, among others, such as by providing a tension system capable of automatically tensioning the drive chains of a coiled tubing injector in proportion to a positive tubing load or a negative tubing load acting on the coiled tubing injector. For example, the tension system can include a reactive chain tension circuit configured to maintain a pressure differential between a fluid pressure within one or more hydraulic motors for turning the drive chains and a fluid pressure within one or more hydraulic cylinders for tensioning the drive chains. In such an example, the reactive tension circuit can receive a pressure signal from the one or more hydraulic motors to adjust the fluid pressure within the one or more hydraulic cylinders, such as in response to an increasing negative load on the one or more hydraulic motors and fall in proportion to a decreasing negative load on the one or more hydraulic motors, such as to ensure the drive chains are under constant tension sufficient to prevent chain bunching in pipe-light operation conditions.

In view of the above, the reactive chain tension circuit can make operating coiled tubing injectors easier for a user while preventing coiled tubing injectors from becoming susceptible to drive chain bunching. For example, rather than closely monitoring the tubing load and operate a chain tension system, the user can be free to devote attention to other aspects of drilling or workovers operations at a well site. Additionally, the reactive chain tension circuit can improve the reliability and overall service life of coiled tubing injectors. For example, as the reactive chain tension circuit can automatically decrease tension within the drive chains as the tubing load decreases, the reactive chain tension circuit can prevent any unnecessary wear of the drive chains, drive sprockets, chain guides, or other components of coiled tubing injectors. Further, the reactive chain tension circuit can help to reduce the overall cost of various operations at well sites. For example, by preventing a user from tensioning the drive chains above a level necessary to prevent chain bunching, the reactive chain tension circuit can reduce the likelihood of operational downtime caused by repair or replacement of a coiled tubing injector.

FIG. **1** illustrates a perspective view of a coiled tubing system **100** in place on a well pad **102**, according to one or more embodiments. As shown in FIG. **1**, the coiled tubing system **100** can include a tubing spool **104** containing a high linear footage of coiled tubing **106**. The coiled tubing system **100** can include a coiled tubing injector **108**. The coiled tubing injector **108** can be operable to advance the coiled tubing **106** into, or withdraw the coiled tubing **106** from, a wellbore of the well pad **102**.

In one example, such as shown in FIG. **1**, the coiled tubing injector **108** can be suspended above a well bore by a crane **110**, such as to help enable the coiled tubing injector **108** to pull the coiled tubing **106** from the tubing spool **104** and lower the coiled tubing **106** into a wellbore. In some examples, the coiled tubing **106** can be connected to various attachments, such as a drilling assembly **112**. In such an example, the coiled tubing **106** can be connected to a drilling fluid source on the well pad **102** to fluidly power the drilling assembly **112** during a well bore drilling operation. The coiled tubing system **100** can include a hydraulic power unit, such as, but not limited to, a power pack **113**. The power pack **113** can be connected to the coiled tubing injector **108** to fluidly power the coiled tubing injector **108**.

FIG. **2** illustrates an isometric view of the coiled tubing injector **108** of FIG. **1**, according to one or more embodiments. FIG. **3** illustrates a side view of the coiled tubing injector **108** of FIGS. **1-2**, according to one or more embodiments. FIGS. **2-3** are discussed below concurrently. The coiled tubing injector **108** is an example coiled tubing injector generally representative of various coiled tubing injectors. For example, the coiled tubing injector **108** can include any of the components or features described in U.S. Pat. Nos. 8,544,536, 8,701,754, or U.S. Pat. No. 10,024,123, each of which is hereby incorporated by reference in its entirety.

As shown in FIG. **2**, the coiled tubing injector **108** can include two or more drive chains **114**, such as a first drive chain **116** (FIG. **2**) and a second drive chain **118** (FIG. **2**). The first drive chain **116** and the second drive chain **118** can each form a continuous loop. The coiled tubing injector **108** can include a drive system **120** (FIG. **2**) for turning or otherwise rotating the first drive chain **116** and the second drive chain **118**. For example, the drive system **120** can include a first drive sprocket **122** (FIG. **2**), a first idler sprocket **124** (shown in shadow in FIG. **3**), a second drive sprocket **126** (FIG. **2**), and a second idler sprocket **128** (shown in shadow in FIG. **3**). The first drive chain **116** can concurrently engage a first drive sprocket **122** and a first idler sprocket **124**; and the second drive chain **118** can concurrently engage a second drive sprocket **126** and a second idler sprocket **128**.

The first drive sprocket **122** can be connected to a first driveshaft **230** (represented in FIG. **4**), the second drive sprocket **126** can be connected to a second driveshaft (represented in FIG. **4**), the first idler sprocket **124** can be connected to a first idler shaft **134** (FIG. **2**), and the second idler sprocket can be connected to a second idler shaft **136** (FIG. **2**). In FIG. **2**, a top surface **125** of the coiled tubing injector **108** is partially cut away to reveal the first drive sprocket **122** and the second drive sprocket **126**. In some examples, the first driveshaft **230**, the second driveshaft **232**, the first idler shaft **134**, and the second idler shaft **136** can extend parallel to, and laterally offset from, one another to enable the first drive sprocket **122**, the first idler sprocket **124**, the second drive sprocket **126**, and the second idler sprocket **128** to be laterally opposed within a common plane.

The drive system **120** can include at least one hydraulic motor. For example, as shown in FIG. **2**, the drive system **120** can include a first hydraulic motor **140** and a second hydraulic motor **142**. The first hydraulic motor **140** and the second hydraulic motor **142** can be fixed displacement motors. The first hydraulic motor **140** and the second hydraulic motor **142** can turn or otherwise rotate the first drive sprocket **122** and the second drive sprocket **126**, respectively. For example, the first driveshaft **230** and the second driveshaft **232** can be operably coupled to the first hydraulic motor **140** and the second hydraulic motor **142**, respectively, such as through a first gearbox **144** (FIG. **2**) and a second gearbox **146** (FIG. **2**), respectively. The first hydraulic motor **140** and the second hydraulic motor **142** can be configured to rotate in opposite directions to thereby cause the first drive chain **116** and the second drive chain **118** to counter-rotate relative to each other. The coiled tubing injector **108** can include a first brake **148** (FIG. **2**) and a second brake **150** (FIG. **2**). The first brake **148** can be operably coupled to the first driveshaft **230** and the second brake **150** can be coupled to the second driveshaft **232**. The first drive chain **116** and the second drive chain **118** can each carry a plurality of grippers **152** (FIG. **2**) shaped to conform to and at least partially encircle the coiled tubing **106** (FIG. **3**) therebetween.

The plurality of grippers **152** can define a grip zone **154** (FIG. **3**). The grip zone **154** can be an area between the first drive chain **116** and the second drive chain **118** in which the plurality of grippers **152** are in contact with and at least partially encircle the coiled tubing **106**. Although not visible, the coiled tubing injector **108** can include at least two skates, one for each of the first drive chain **116** and the second drive chain **118**, and a plurality of hydraulic cylinders for pushing the at least two skates toward each other. The at least two skates move the plurality of grippers **152** within the grip zone **154** toward each other under hydraulic pressure provided by the hydraulic cylinders to thereby cause the plurality of grippers **152** to forcibly engage the coiled tubing **106**. Examples of such skates and hydraulic cylinders are shown in U.S. Pat. Nos. 5,309,990 and 5,918,671, which are hereby incorporated by reference in their entirety.

The coiled tubing injector **108** can include a tension system **156** (FIG. **2**). The tension system **156** can include the first idler sprocket **124**, the second idler sprocket **128**, the first idler shaft **134**, and the second idler shaft **136**. For example, the first idler shaft **134** and the second idler shaft **136** can be moveably connected to a frame **161** (FIG. **2**) configured to support various components of the coiled tubing injector **108**, such as including, but not limited to, the first driveshaft **230**, the second driveshaft **232**, the first idler shaft **134**, and the second idler shaft **136**. The tension system **156** can include at least one hydraulic cylinder, such as a one or more first hydraulic cylinders **158** and the one or more second hydraulic cylinders **160**.

The one or more first hydraulic cylinders **158** and the one or more second hydraulic cylinders **160** can be arranged within the frame **161** with respect to the first idler shaft **134** and the second idler shaft **136**, respectively, such as to enable the one or more first hydraulic cylinders **158** to adjust the distance between the first driveshaft **230** and the first idler shaft **134**, and the distance between the second driveshaft **232** and the second idler shaft **136**, by translating the first idler shaft **134** and the second idler shaft **136** with respect to the frame **161**. The one or more first hydraulic cylinders **158** and the one or more second hydraulic cylinders **160** are thereby operable to place the first drive chain **116** and the second drive chain **118** under constant tension during rotation of the first drive sprocket **122**, the first idler sprocket **124**, the second drive sprocket **126**, and the second idler sprocket **128**. The tension system **156** can include a reactive chain tension circuit **262** (FIG. **4**).

The reactive chain tension circuit **262** can be configured to automatically adjust the fluid pressure within the one or more first hydraulic cylinders **158** and the one or more second hydraulic cylinders **160**, and thereby automatically tension the first drive chain **116** and the second drive chain **118**. For example, the reactive chain tension circuit **262** can be in fluid communication with the first hydraulic motor **140** and/or the second hydraulic motor **142** to receive a pressure signal indicative of a positive or a negative tubing load on the coiled tubing injector **108**. That is, the first hydraulic motor **140** and the second hydraulic motor **142** can be the primary motive element driving the coiled tubing **106**, and the amount of power used (in the form of hydraulic pressure) to advance or withdraw the coiled tubing **106** into, or out of, a wellbore is related to the upward or downward force on the coiled tubing **106**. The reactive chain tension circuit **262** can then use the pressure signal to increase or decrease the fluid pressure within the one or more first hydraulic cylinders **158** and the one or more second hydraulic cylinders **160** to maintain a pressure differential between the fluid pressure within the first hydraulic motor **140** and the second hydraulic motor **142** and the fluid pressure within the one or more first hydraulic cylinders **158** and the one or more second hydraulic cylinders **160**.

Such a pressure differential can include a first pressure threshold and a second pressure threshold. In one example, the first pressure threshold can be a minimum pressure, based on a tubing load on the coiled tubing injector **108**, selected to prevent bunching of the first drive chain **116** and the second drive chain **118**; and the second pressure threshold can be a maximum pressure, based on a tubing load on the coiled tubing injector **108**, before which the first drive chain **116** and the second drive chain **118** experience excessive tension. In view of the above, the tension system **256** can automatically tension the first drive chain **116** and the second drive chain **118** based on a tubing load on the coiled tubing injector **108**.

FIG. **4** illustrates a hydraulic circuit of the coiled tubing injector of FIGS. **1-3** including an example reactive chain tension circuit **262**, according to one or more embodiments. In FIG. **4**, the power pack **113**, the first drive sprocket **122**, the second drive sprocket **126**, the first hydraulic motor **140**, the second hydraulic motor **142**, the first brake **148**, the second brake **150**, the one or more first hydraulic cylinders **158**, and the one or more second hydraulic cylinders **160** shown in FIG. **2** are discussed with regard to reference numbers **213**, **222**, **226**, **248**, **250**, **258**, and **260**, respectively. The hydraulic circuit **200** is one example of a simplified hydraulic circuit that can be used with the coiled tubing injector **108** shown in FIGS. **1-3** above. The hydraulic circuit **200** can include a drive circuit **201**, such as formed by a drive line **266** and a return line **268**. The drive line **266** and the return line **268** can be configured for connection to the power pack **213**, such as to supply the hydraulic circuit **200** with pressurized hydraulic fluid at a preset or charge pressure. Fluid pressure within the drive line **266** can change in response to a negative tubing load on the coiled tubing injector **108**, and fluid pressure within the return line **268** can change in response to a positive tubing load on the coiled tubing injector **108**.

The first hydraulic motor **240** can be connected to the drive line **266** through branch **266**A, such as via port **267**A of a first counterbalance valve **267**. The second hydraulic motor **242** can be connected to the drive line **266** through branch **266**B, such as via port **269**A of a second counterbalance valve **269**. The first hydraulic motor **240** can be connected to the return line **268** through branch **268**A, such as via port **267**B of the first counterbalance valve **267**. The second hydraulic motor **242** can be connected to the return line **268** through branch **268**B, such as via port **269**B of the second counterbalance valve **269**. The first counterbalance valve **267** and the second counterbalance valve **269** can be configured to regulate the flow of hydraulic fluid through the first hydraulic motor **240** and the second hydraulic motor **242**, respectively. For example, the first counterbalance valve **267** and the second counterbalance valve **269** can be operable to start, stop, or otherwise control the speed of the first hydraulic motor **240** and the second hydraulic motor **242**, respectively.

The first hydraulic motor **240** can include a shaft **241** connected to the first brake **248** and the first gearbox **244**, which can in turn rotate the first drive sprocket **222** via an output shaft. The second hydraulic motor **242** can include a shaft **243** connected to the second brake **250** and the second gearbox **246**, which can in turn rotate the second drive sprocket **226**. The tension system **156** (FIG. **1**) can include a cylinder drive line **270** and an external fluid source **285**. The cylinder drive line **270** can be connected directly to the one or more first hydraulic cylinders **258** and the one or more second hydraulic cylinders **260**. In one example, such as shown in FIG. **4**, the one or more first hydraulic cylinders **258** and the one or more second hydraulic cylinders **260** each include two hydraulic cylinders. The cylinder drive line **270** can be connected to the external fluid source **285**. The external fluid source **285** can supply pressurized hydraulic fluid to cylinder drive line **270**. Fluid pressure within the cylinder drive line **270** can dictate the amount of tension within the first drive chain **116** (FIG. **2**) and the second drive chain **118** (FIG. **2**). Pressurized hydraulic fluid within the cylinder drive line **270** can be discharged to a drain line **271** through a brake manifold assembly **272** for controlling the first brake **248** and the second brake **250**, such as through lines **273**, **274**, **275**, and **276**.

A user can manually adjust the fluid pressure within the cylinder drive line **270**, such as via one or more user inputs to the external fluid source **285**. For example, a user can increase or decrease the fluid pressure within the cylinder drive line **270** to a limit (e.g., a first pressure threshold or a second pressure threshold) implemented by the reactive chain tension circuit **262**. The reactive chain tension circuit **262** can include a pilot line **277**. The pilot line **277** can be in fluid communication with the drive line **266**. For example, the pilot line **277** can be connected to a first port **240**A of the first hydraulic motor **240**. The first port **240**A can be a port that is in fluid communication with the drive line **266**, at least in that fluid pressure at the first port **240**A can be equal to the fluid pressure within the drive line **266**. In other examples, the pilot line **277** can be connected directly to the drive line **266**, or to a first port **242**A of the second hydraulic motor **242**.

The reactive chain tension circuit **262** can include a first valve **279** and a second valve **280**. The first valve **279** and the second valve **280** can be connected to the pilot line **277** in parallel, such as through branch **277**A and branch **277**B, respectively. The pilot line **277** can thereby provide a pressure signal indicative of a tubing load on the coiled tubing injector **108** to the reactive chain tension circuit **262**. The first valve **279** and the second valve **280** can be, for example, but not limited to, pilot-operated pressure control valves. The reactive chain tension circuit **262** can include an intermediary line **281** and a tension line **282**. The first valve **279** can be connected to the second valve **280** through the intermediary line **281**. The tension line **282** can be connected to the cylinder drive line **270**. The intermediary line **281** can be connected to the tension line **282**, and thereby the one or more first hydraulic cylinders **258** and the one or more second hydraulic cylinders **260**, through the tension line **282**.

The reactive chain tension circuit **262** can include an auxiliary fluid source **283** and an auxiliary line **284**. The auxiliary fluid source **283** can be connected to the first valve **279** through the auxiliary line **284**. In some examples, the auxiliary line **284** can include an adjustable orifice **286**. The adjustable orifice **286** can be operable to control a fluid flow rate between the auxiliary fluid source **283** and the first valve **279**. In one example, the first valve **279** can be configured to maintain the fluid pressure within the one or more first hydraulic cylinders **258** and the one or more second hydraulic cylinders **260** above a first pressure threshold. The first pressure threshold can be a relative fluid pressure set at a fixed interval above, or below, the pressure signal within the pilot line **277**, such as selected to meet the unique requirements of an individual coiled tubing injector. In one example, the first pressure threshold can be a pressure about 100 pounds per square inch greater than the pressure signal (e.g., the fluid pressure within the pilot line **277**) provided by the branch **277**A to the first valve **279**.

The first valve **279** can be controlled by the pressure signal provided by the branch **277**A of the pilot line **277**. For example, when the fluid pressure within the one or more first hydraulic cylinders **258** and the one or more second hydraulic cylinders **260** is less than the first pressure threshold, the first valve **279** can open to enable fluid from the auxiliary fluid source **283** to flow through the first valve **279** until the fluid pressure within the one or more first hydraulic cylinders **258** and the one or more second hydraulic cylinders **260** is equal to the first pressure threshold. Once the fluid pressure within the tension line **282** is equal to the first pressure threshold, the first valve **279** can close to prevent fluid from the auxiliary fluid source **283** from flowing through the first valve **279**, such as until the pressure signal within the pilot line **277** indicates the pressure within the tension line **282** is below the first pressure threshold. In view of the above the first valve **279** can selectively connect the auxiliary fluid source **283** to the one or more first hydraulic cylinders **258** and the one or more second hydraulic cylinders **260** based on the pressure signal from the pilot line **277**.

The reactive chain tension circuit **262** can include a discharge line **287**. The discharge line **287** can be connected to the drain line **271** via the brake manifold assembly **272**, such as through lines **274**, **275**, and **276**. The second valve **280** can be configured to maintain the fluid pressure within the one or more first hydraulic cylinders **258** and the one or more second hydraulic cylinders **260** below a second pressure threshold. The second pressure threshold can be a relative fluid pressure set at a fixed interval above, or below, the pressure signal within the pilot line **277**, such as selected to meet the unique requirements an individual coiled tubing injector. In one non-limiting example, the second pressure threshold can be a pressure about 400 pounds per square inch greater than the pressure signal (e.g., the fluid pressure within the pilot line **277**) provided by the branch **277**B to the second valve **280**. The second valve **280** can be controlled by the pressure signal provided by the branch **277**B of the pilot line **277**.

For example, when the fluid pressure within the one or more first hydraulic cylinders **258** and the one or more second hydraulic cylinders **260** is equal to the second pressure threshold, the second valve **280** can open to enable fluid to flow through the second valve **280** into the discharge line **287** until the fluid pressure within the tension line **282** is below the second pressure threshold. Once the fluid pressure within the tension line **282** is below the second pressure threshold, the second valve **280** can close to prevent fluid from flowing through the second valve **280** until the pressure signal within the pilot line **277** is below the second pressure threshold. In view of the above, the second valve **280** can selectively connect the tension line **282** to the discharge line **287** based on the pressure signal from the pilot line **277**.

In some examples, the intermediary line **281** can include a directional control valve **288**. The directional control valve **288** can be, but is not limited to, a check valve. The directional control valve **288** can be configured to prevent fluid flow from the tension line **282** to the first valve **279**, such as to help reduce pressure leakage associated with the one or more first hydraulic cylinders **258** and the one or more second hydraulic cylinders **260**. For example, the directional control valve **288** can be located on the intermediary line **281** downstream of the first valve **279**, such as between the first valve **279** and a point at which the intermediary line **281** is connected to the tension line **282**. In some examples, the reactive chain tension circuit **262** can include a two-way valve **289**. The two-way valve **289** can be, for example, but is not limited, to a manually operable ball valve. The two-way valve **289** can be opened by a user to operably connect, or disconnect, the reactive chain tension circuit **262** to the one or more first hydraulic cylinders **258** and the one or more second hydraulic cylinders **260** by enabling or preventing fluid flow through the tension line **282**.

FIG. **5** is an example graph **300** illustrating hydraulic fluid pressure with the reactive chain tension circuit **262** of FIG. **4** as a function of tubing load of the coiled tubing injector of FIGS. **1**-**3**. Section **302** of the graph **300** can represent a period where the coiled tubing injector **108** is experiencing a positive tubing load, in pounds. A positive tubing load can indicate the coiled tubing **106** is in a pipe-heavy state; and the first hydraulic motor **240** (FIG. **4**) and the second hydraulic motor **242** (FIG. **4**) are working to resist a downward force of gravity acting on the coiled tubing **106**. Section **304** of the graph **300** can represent a period where the coiled tubing injector **108** is experiencing a negative tubing load, in pounds. A negative tubing load can indicate that the coiled tubing is in a pipe-light state; and the first hydraulic motor **240** and the second hydraulic motor **242** are working to overcome an upward force acting on the coiled tubing **106**, such as from within a wellbore.

A line **306** can represent an example minimum pressure within the one or more first hydraulic cylinders **258** (FIG. **4**) and the one or more second hydraulic cylinders **260** (FIG. **4**) relative to a tubing load, such as necessary or recommended to prevent chain bunching. Traditionally, this minimum pressure is maintained by a user, such as by manually increasing or decreasing the fluid pressure within the one or more first hydraulic cylinders **258** (FIG. **4**) and the one or more second hydraulic cylinders **260** using the external fluid source **285** (FIG. **4**) A line **308** can represent action, in the form of a pressure curve, of the first valve **279** (FIG. **4**) in response to the pressure signal provided by the pilot line **277** (FIG. **4**). The first pressure threshold is shown by the line **308** as 100 pounds per square inch above the pressure signal provided by the pilot line **277**. A line **310** can represent action, in the form of a pressure curve, of the second valve **280** (FIG. **4**) in response to the pressure signal provided by the pilot line **277**. The second pressure threshold is shown by the line **310** as 400 pounds per square inch above the pressure signal provided by the pilot line **277**.

The first valve **279** can maintain the fluid pressure within the reactive chain tension circuit **262**, and thereby the one or more first hydraulic cylinders **258** and the one or more second hydraulic cylinders **260**, above the line **306** (e.g., the minimum pressure) and the minimum pressure threshold when the coiled tubing injector **108** is experiencing a positive load. For example, the fluid pressure within the pilot line **277** will not increase above a charge pressure (illustrated in FIG. **5** as 500 pounds per square inch) provided by the power pack **213** (FIG. **4**) of the drive circuit **201**, as only the fluid pressure within the return line **268** will increase when the coiled tubing injector **108** is experiencing a positive tubing load. As such, in section **302**, the first valve **279** will generally be in a closed state to continuously maintain the fluid pressure within the one or more first hydraulic cylinders **258** and the one or more second hydraulic cylinders **260** above the line **306**.

The first valve **279** can maintain the fluid pressure within the reactive chain tension circuit **262**, and thereby the one or more first hydraulic cylinders **258** and the one or more second hydraulic cylinders **260**, above the line **306** (e.g., the minimum pressure) and the minimum pressure threshold when the coiled tubing injector **108** is experiencing a negative load. For example, as the fluid pressure within the pilot line **277** will increase in response to an increasing negative tubing load on the coiled tubing injector **108**, the first valve **279** will open to enable fluid from the auxiliary fluid source **283** (FIG. **4**) to flow through the first valve **279** until the fluid pressure within the one or more first hydraulic cylinders **258** and the one or more second hydraulic cylinders **260** is equal to the first pressure threshold. As such, in section **304**, the first valve **279** will generally alternate between an open state and a closed state to continuously maintain the fluid pressure within the one or more first hydraulic cylinders **258** and the one or more second hydraulic cylinders **260** above the pressure signal provided by the pilot line **277**.

The second valve **280** can maintain the fluid pressure within the reactive chain tension circuit **262**, and thereby the one or more first hydraulic cylinders **258** and the one or more second hydraulic cylinders **260**, below a second pressure threshold. For example, when the fluid pressure within the pilot line **277** decreases in response to a decreasing negative tubing load on the coiled tubing injector **108**, the second valve **280** can open to enable fluid from the reactive chain tension circuit **262** to flow through the second valve **280** until the fluid pressure within the one or more first hydraulic cylinders **258** and the one or more second hydraulic cylinders **260** is less than the second pressure threshold.

Additionally, during section **302** or section **304**, a user can operate the external fluid source **285** to manually increase the fluid pressure within the one or more first hydraulic cylinders **258** and the one or more second hydraulic cylinders **260** up to the second pressure threshold. Upon the occurrence of such an event, the second valve **280** can open to discharge pressure through the discharge line **287** (FIG. **4**) until the pressure signal provided to the second valve **280** by the pilot line **277** falls below the second pressure threshold. Additionally, during section **302** or section **304**, a user can operate the external fluid source **285** to manually decrease the fluid pressure within the one or more first hydraulic cylinders **258** and the one or more second hydraulic cylinders **260** to first second pressure threshold. Upon the occurrence of such an event, the first valve **279** can open to enable fluid from the auxiliary fluid source **283** (FIG. **4**) to flow through the first valve **279** until the fluid pressure within the one or more first hydraulic cylinders **258** and the one or more second hydraulic cylinders **260** is again equal to the first pressure threshold.

FIG. **6** illustrates a hydraulic circuit **400** of the coiled tubing injector **108** of FIGS. **1-3** including an example reactive chain tension circuit **462**, according to one or more examples. In FIG. **6**, the first hydraulic motor **240**, the first port **240**A, the second hydraulic motor **242**, the port **242**A, the one or more first hydraulic cylinders **258**, the one or more second hydraulic cylinders **260**, the drive line **266**, the drain line **271**, the second valve **280**, the intermediary line **481**, the tension line **482**, the discharge line **487**, the directional control valve **488**, and the two-way valve **489** are discussed with regard to reference numbers **440**, **440**A, **442**, **442**A, **458**, **460**, **466**, **471**, **480**, **481**, **482**, **487**, **488**, and **489**, respectively. The hydraulic circuit **400** is one example of a simplified hydraulic circuit that can be used with the coiled tubing injector **108** shown in FIGS. **1-3** above. The hydraulic circuit **400** can be similar to the hydraulic circuit **200** discussed with regard to FIG. **4** above, except in that the reactive chain tension circuit **462** can be realized using a different combination of components. The reactive chain tension circuit **462** can include a pilot line **490**, a flow divider **491**, the second valve **480**, the intermediary line **481**, the tension line **482**, and the discharge line **487**.

The pilot line **490** can be in fluid communication with the drive line **466**. For example, the pilot line **490** can be connected to a first port **440**A of the first hydraulic motor **440**. The first port **440**A can be a port that is in fluid communication with the drive line **466**, at least in that fluid pressure at the first port **440**A can be equal to the fluid pressure within the drive line **466**. In other examples, the pilot line **490** can be connected directly to the drive line **466**, or to a first port **442**A of the second hydraulic motor **442**. The flow divider **491** and the second valve **480** can be connected to the pilot line **490** in parallel, such as through branch **490**A and branch **490**B, respectively. The pilot line **490** can thereby provide a pressure signal indicative of a tubing load on the coiled tubing injector **108** to the reactive chain tension circuit **462**. The second valve **480** can be connected to the flow divider **491** through the intermediary line **481**.

In some examples, the branch **490**A of the pilot line **490** can include an adjustable orifice **493**. The adjustable orifice **493** can be operable to control a fluid flow rate between the first hydraulic motor **440** and the flow divider **491**. For example, the adjustable orifice **493** can be located on branch **490**A of the pilot line **490**. In some examples, the pilot line **490** can include a pressure reducing valve **494**. The pressure reducing valve **494** can be configured to limit a maximum fluid pressure at the flow divider **491** and the second valve **480**. The flow divider **491** can include a first port **495**, a second port **496**, and a third port **497**. In one example, the flow divider **491** can be configured to maintain the fluid pressure within the one or more first hydraulic cylinders **458** and the one or more second hydraulic cylinders **460** above a first pressure threshold. For example, the flow divider **491** can be configured as a pressure intensifier. In such an example, the first port **495** can be connected to the branch **490**A of the pilot line **490**, the second port **496** can be connected to the drain line **471** through a flow line **498**, and the third port **497** can be connected to the second valve **480** via the intermediary line **481**.

In operation, fluid pressure at the third port **497**, and the thereby the tension line **482**, the one or more first hydraulic cylinders **458**, and the one or more second hydraulic cylinders **460**, will be proportionally greater than the fluid pressure at the first port **495** and the pilot line **490** by the amount of fluid pressure that the second port **496** and the flow line **498** direct to the drain line **471**. For example, if the flow divider **491** is has a two-to-one ratio between the third port **497** and the second port **496**, the second port **496** can divert one-third of the fluid pressure at the first port **495**, and therefore the fluid pressure within the one or more first hydraulic cylinders **458** and the one or more second hydraulic cylinders **460** will be one-third greater than the fluid pressure within the pilot line **490**. In this way, the flow divider **491** can maintain the fluid pressure within the one or more first hydraulic cylinders **458** and the one or more second hydraulic cylinders **460** above a first pressure threshold, such as when the first pressure threshold is a pressure greater than the fluid pressure within the first hydraulic motor **240** and the drive line **466**.

In other examples, the flow divider **491** can be configured as a pressure reducer. In such an example, such as shown in FIG. **4**, the first port **495** can be connected to the second valve **480** via the intermediary line **481**, the second port **496** can be connected to the flow line **498**, and the third port **497** can be connected the branch **490**A of the pilot line **490**. In operation, fluid pressure at the first port **495**, and the thereby the tension line **482**, the one or more first hydraulic cylinders **458**, and the one or more second hydraulic cylinders **460**, will be proportionally less than the amount of fluid pressure at the third port **497** and the pilot line **490** by the amount of the fluid pressure that the second port **496** and the flow line **498** bring into the flow divider **491** from the drain line **471**.

For example, if the flow divider **491** has a two-to-one ratio between the third port **497** and the second port **496**, and the second port **496** contributes zero, or otherwise a nominal, fluid pressure to the second port **496**, the fluid pressure within the one or more first hydraulic cylinders **458** and the one or more second hydraulic cylinders **460** will be one-third less than the fluid pressure within the pilot line **490**. In this way, the flow divider **491** can maintain the fluid pressure within the one or more first hydraulic cylinders **458** and the one or more second hydraulic cylinders **460** above a first pressure threshold, such as when the first pressure threshold is a pressure less than the fluid pressure within the first hydraulic motor **440** and the drive line **466**.

The flow divider **491** can help the reactive chain tension circuit **462** meet the unique requirements of different coiled tubing injectors. For example, the flow divider **491** can be selected based on various components of a coiled tubing injector, such as to help ensure that a pressure curve defined by fluid flow through the flow divider **491** can closely correspond to a minimum pressure within the one or more first hydraulic cylinders **458** and the one or more second hydraulic cylinders **460** relative to a tubing load on the coiled tubing injector. In one such example, the flow divider **491** can be selected to control fluid flow within the reactive chain tension circuit **462** such that the line **308** (FIG. **5**) and the line **310** (FIG. **5**) shown in section **304** (FIG. **5**) of the graph **300** (FIG. **5**) extend parallel to, and laterally offset from, the line **306** (e.g., the minimum pressure).

FIG. **7** illustrates an example method **500** of using a coiled tubing injector. Any of the above examples of the coiled tubing injector **108**, and the reactive chain tension circuits **262** and **462**, described with regard to FIGS. **1-5** above can be used in the method **500** of using a coiled tubing injector. The discussed steps or operations can be performed in parallel or in a different sequence without materially impacting other operations. The method **500** as discussed includes operations that can be performed by multiple different actors, devices, and/or systems. It is understood that subsets of the operations discussed in the method **500** can be attributable to a single actor device, or system, and could be considered a separate standalone process or method.

The method **500** can optionally include operation **502**. The operation **502** can include connecting the reactive chain tension circuit to the at least one hydraulic motor. For example, a user can open a two-way valve to operably connect the reactive chain tension circuit to the at least one hydraulic cylinder to thereby enable fluid flow through the reactive chain tension circuit to the at least one hydraulic cylinder. The method operation can optionally include operation **504**. The operation **504** can include adjusting an orifice between the reactive chain tension circuit and the drive line. For example, a user can engage an adjustable orifice to set or otherwise adjust a fluid flow rate between the at least one hydraulic motor and the reactive chain tension circuit.

The method **500** can include operation **506**. The operation **506** can include activating the drive system to begin moving the coiled tubing through the grip zone toward a wellbore. For example, a user can engage with, such as via one or more user inputs to, a hydraulic power pack or power unit to charge the drive line and a return connected to the at least one hydraulic motor to enable the at least one hydraulic motor to begin turning the two or more drive chains carrying the plurality of grippers.

The method can include operation **508**. The operation **508** can include tensioning the two or more drive chains by a reactive chain tension circuit based on a fluid pressure within the at least one hydraulic motor, by maintaining a pressure differential between the fluid pressure within the at least one hydraulic motor and a fluid pressure within at least one hydraulic cylinder for tensioning the at least two drive chains. For example, when the drive system begins moving the coiled tubing through the grip zone, the reactive chain tension circuit can receive a pressure signal from the at least one hydraulic motor indicative of a tubing load on the coiled tubing injector to enable the reactive tension circuit to automatically adjust the tension within the first drive chain and the second drive chain based on the tubing load, such as by maintaining the fluid pressure within the at least one hydraulic cylinder at a set or otherwise fixed interval above or below the pressure signal.

In some examples, the operation **508** can include actuating a first valve to maintain a fluid pressure within the hydraulic reactive tension circuit above a first pressure threshold. For example, when the fluid pressure within the reactive chain tension circuit, and thereby the at least one hydraulic cylinder, is less than the first pressure threshold, the first valve can open to enable fluid, such as from an external fluid source, to flow through the first valve until the fluid pressure within the at least one hydraulic cylinder is equal to the first pressure threshold. In some examples, the operation **508** can include actuating a second valve to maintain the fluid pressure within the hydraulic reactive tension circuit below a second pressure threshold. For example, when the fluid pressure within the reactive chain tension circuit, and thereby the at least one hydraulic cylinder, is equal to the second pressure threshold, the second valve can open to enable fluid to flow through the second valve to a drain line until the fluid pressure within the at least one hydraulic cylinder is below the second pressure threshold.

In some examples, the operation **508** can include directing hydraulic fluid through a flow divider to maintain a fluid pressure within the hydraulic reactive tension circuit above a first pressure threshold. For example, the flow divider can be configured as a pressure intensifier, and fluid within the pilot line at the pressure within the drive line and the least one hydraulic motor can be passed through the flow divider to increase the fluid pressure by an amount equal to or greater than the first pressure threshold.

The foregoing systems and devices, etc. are merely illustrative of the components, interconnections, communications, functions, etc. that can be employed in carrying out examples in accordance with this disclosure. Different types and combinations of sensor or other portable electronics devices, computers including clients and servers, implants, and other systems and devices can be employed in examples according to this disclosure.

The above detailed description includes references to the accompanying drawings, which form a part of the detailed description. The drawings show, by way of illustration, specific embodiments in which the invention can be practiced. These embodiments are also referred to herein as "examples." Such examples can include elements in addition to those shown or described. However, the present inventor also contemplates examples in which only those elements shown or described are provided.

Moreover, the present inventor also contemplates examples using any combination or permutation of those elements shown or described (or one or more aspects thereof), either with respect to a particular example (or one or more aspects thereof), or with respect to other examples (or one or more aspects thereof) shown or described herein. In the event of inconsistent usages between this document and any documents so incorporated by reference, the usage in this document controls.

In this document, the terms "a" or "an" are used, as is common in patent documents, to include one or more than one, independent of any other instances or usages of"at least one" or "one or more." In this document, the term "or" is used to refer to a nonexclusive or, such that "A or B" includes "A but not B," "B but not A," and "A and B," unless otherwise indicated. In this document, the terms "including" and "in which" are used as the plain-English equivalents of the respective terms "comprising" and "wherein." Also, in the following claims, the terms "including" and "comprising" are open-ended, that is, a system, device, article, composition, formulation, or process that includes elements in addition to those listed after such a term in a claim are still deemed to fall within the scope of that claim. Moreover, in the following claims, the terms "first," "second," and "third," etc. are used merely as labels, and are not intended to impose numerical requirements on their objects.

The above description is intended to be illustrative, and not restrictive. For example, the above-described examples (or one or more aspects thereof) may be used in combination with each other. Other embodiments can be used, such as by one of ordinary skill in the art upon reviewing the above description. The Abstract is provided to comply with 37 C.F.R. § 1.72(b), to allow the reader to quickly ascertain the nature of the technical disclosure. It is submitted with the understanding that it will not be used to interpret or limit the scope or meaning of the claims. Also, in the above Detailed Description, various features may be grouped together to streamline the disclosure.

This should not be interpreted as intending that an unclaimed disclosed feature is essential to any claim. Rather, inventive subject matter may lie in less than all features of a particular disclosed embodiment. Thus, the following claims are hereby incorporated into the Detailed Description as examples or embodiments, with each claim standing on its own as a separate embodiment, and it is contemplated that such embodiments can be combined with each other in various combinations or permutations. The scope of the invention should be determined with reference to the appended claims, along with the full scope of equivalents to which such claims are entitled.

EXAMPLES

The following, non-limiting examples, detail certain aspects of the present subject matter to solve the challenges and provide the benefits discussed herein, among others.

Example 1 is a coiled tubing injector comprising: two or more drive chains each forming a continuous loop and carrying a plurality of grippers for engaging coiled tubing within a grip zone defined between the two or more drive chains; a drive system including: a first drive sprocket engaged with a first drive chain of the two or more drive chains; a second drive sprocket engaged with a second drive chain of the two or more drive chains; at least one hydraulic motor for turning the first drive sprocket and the second drive sprocket, the at least one hydraulic motor connected to a drive line and a return line forming a drive circuit for fluidly powering the at least one hydraulic motor; and a tension system including: at least one hydraulic cylinder for tensioning the two or more drive chains, and a reactive chain tension circuit for automatically tensioning the two or more drive chains by maintaining a pressure differential between a fluid pressure within the drive line and a fluid pressure within the at least one hydraulic cylinder.

In Example 2, the subject matter of Example 1 includes, where the reactive chain tension circuit includes a first valve configured to maintain the fluid pressure within the at least one hydraulic cylinder above a first pressure threshold; and a second valve configured to maintain the fluid pressure within the at least one hydraulic cylinder below a second pressure threshold.

In Example 3, the subject matter of Example 2 includes, wherein the reactive chain tension circuit includes a pilot line connecting the first valve and the second valve in parallel to the drive line to provide the first valve and the second valve with a pressure signal indicative of a tubing load on the coiled tubing injector.

In Example 4, the subject matter of Example 3 includes, wherein the at least one hydraulic motor includes a first port in fluid communication with the drive line and the pilot line of the reactive chain tension circuit.

In Example 5, the subject matter of Example 4 includes, wherein the tension system includes an auxiliary fluid source; and wherein the first valve is configured to maintain the fluid pressure within the at least one hydraulic cylinder above the first pressure threshold by selectively connecting the auxiliary fluid source to the at least one hydraulic cylinder based on the pressure signal.

In Example 6, the subject matter of Example 5 includes, wherein the first valve is connected to the auxiliary fluid source with an auxiliary line including an adjustable orifice operable to control a fluid flow rate between the auxiliary fluid source and the reactive chain tension circuit.

In Example 7, the subject matter of Examples 5-6 includes, wherein the first valve and the second valve are connected to the reactive chain tension circuit by a tension line, the tension line including a two-way valve operable to disconnect the reactive chain tension circuit from the tension system.

In Example 8, the subject matter of Example 7 includes, wherein the first valve and the second valve are connected to each other via an intermediary line extending therebetween, the intermediary line including a directional control valve positioned to prevent fluid flow from the tension line to the first valve to reduce leakage associated with the at least one hydraulic cylinder, and wherein the tension line is connected to the intermediary line between the directional control valve and the second valve.

In Example 9, the subject matter of Example 8 includes, wherein the second valve is configured to maintain the fluid pressure within the at least one hydraulic cylinder below the second pressure threshold by selectively connecting the tension line to a discharge line.

In Example 10, the subject matter of Example 9 includes, an external fluid source connected to the at least one hydraulic cylinder, wherein the external fluid source is manually operable to increase the fluid pressure within the at least one hydraulic cylinder to the second pressure threshold or decrease the fluid pressure within the at least one hydraulic cylinder to the first pressure threshold.

Example 11 is a coiled tubing injector comprising two or more drive chains each forming a continuous loop and carrying a plurality of grippers for engaging coiled tubing within a grip zone defined between the two or more drive chains; a drive system including: a first drive sprocket engaged with a first drive chain of the two or more drive chains; a second drive sprocket engaged with a second drive chain of the two or more drive chains; a first hydraulic motor for turning the first drive sprocket; a second hydraulic motor for turning the second drive sprocket, wherein the first hydraulic motor and the second hydraulic motor are connected in parallel to a drive line and a return line forming a drive circuit for fluidly powering the first hydraulic motor and the second hydraulic motor; and a tension system including: one or more first hydraulic cylinders for tensioning the first drive chain; one or more second hydraulic cylinders for tensioning the second drive chain; and a reactive chain tension circuit for automatically tensioning the first drive chain and the second drive chain by maintaining a pressure differential between a fluid pressure within the drive line and a fluid pressure within the first hydraulic cylinder and the second hydraulic cylinder, wherein the reactive chain tension circuit is connected to a first port of the first hydraulic motor via a pilot line to provide the reactive chain tension circuit with a pressure signal indicative of a tubing load on the coiled tubing injector.

In Example 12, the subject matter of Example 11 includes, wherein the reactive chain tension circuit includes: a flow divider configured to maintain the fluid pressure within the first hydraulic cylinder and the second hydraulic cylinder above a first pressure threshold; and a pilot operated pressure control valve configured to maintain the fluid pressure within the first hydraulic cylinder and the second hydraulic cylinder below a second pressure threshold, wherein the pilot line connects the flow divider and the pilot operated pressure control valve to the drive line in parallel.

In Example 13, the subject matter of Example 12 includes, wherein the pilot line includes a pressure reducing valve configured to limit a maximum fluid pressure at the flow divider and the pilot operated pressure control valve.

In Example 14, the subject matter of Example 13 includes, wherein the pilot line includes an adjustable orifice operable to control a fluid flow rate between the first hydraulic motor and the pressure reducing valve; and wherein the reactive chain tension circuit includes a two-way valve operable to disconnect the reactive chain tension circuit from the drive line.

Example 15 is a method of using a coiled tubing injector including two or more drive chains carrying a plurality of grippers for engaging coiled tubing within a grip zone defined between a first drive chain and a second drive chain, and a drive system for turning the two or more drive chains and including at least one hydraulic motor connected to a drive line for fluidly powering the at least one hydraulic motor, the method comprising: activating the drive system to begin moving the coiled tubing through the grip zone toward a wellbore; and tensioning the two or more drive chains by a reactive chain tension circuit based on a fluid pressure within the at least one hydraulic motor, by maintaining a pressure differential between the fluid pressure within the at least one hydraulic motor and a fluid pressure within at least one hydraulic cylinder for tensioning the first drive chain and the second drive chain.

In Example 16, the subject matter of Example 15 includes, wherein tensioning the two or more drive chains by the reactive chain tension circuit includes actuating a first valve to maintain a fluid pressure within the reactive chain tension circuit above a first pressure threshold; and actuating a second valve to maintain the fluid pressure within the reactive chain tension circuit below a second pressure threshold.

In Example 17, the subject matter of Examples 15-16 includes, wherein tensioning the two or more drive chains by the reactive chain tension circuit includes: directing hydraulic fluid through a flow divider to maintain a fluid pressure within the reactive chain tension circuit above a first pressure threshold, and actuating a pilot operated pressure control valve to maintain the fluid pressure within the reactive chain tension circuit below a second threshold pressure.

In Example 18, the subject matter of Example 17 includes, wherein directing hydraulic fluid through a flow divider to increase a fluid pressure within the reactive chain tension circuit to a first threshold pressure includes actuating a pressure reducing valve to limit a fluid pressure at the flow divider and the pilot operated pressure control valve.

In Example 19, the subject matter of Examples 15-18 includes, wherein tensioning the two or more drive chains by the reactive chain tension circuit includes first adjusting an orifice between the reactive chain tension circuit and the drive line.

In Example 20, the subject matter of Examples 15-19 includes, wherein tensioning the two or more drive chains by the reactive chain tension circuit first includes first connecting the reactive chain tension circuit to the at least one hydraulic motor.

Example 21 is at least one machine-readable medium including instructions that, when executed by processing circuitry, cause the processing circuitry to perform operations to implement of any of Examples 1-20.

Example 22 is an apparatus comprising means to implement of any of Examples 1-20.

Example 23 is a system to implement of any of Examples 1-20.

Example 24 is a method to implement of any of Examples 1-20.

What is claimed is:

1. A coiled tubing injector comprising:

two or more drive chains each forming a continuous loop and carrying a plurality of grippers for engaging coiled tubing within a grip zone defined between the two or more drive chains;

a drive system including:

a first drive sprocket engaged with a first drive chain of the two or more drive chains;

a second drive sprocket engaged with a second drive chain of the two or more drive chains;

at least one hydraulic motor for turning the first drive sprocket and the second drive sprocket, the at least one hydraulic motor connected to a drive line and a return line forming a drive circuit for fluidly powering the at least one hydraulic motor; and a tension system including:

at least one hydraulic cylinder for tensioning the two or more drive chains; and

a reactive chain tension circuit for automatically tensioning the two or more drive chains by maintaining a pressure differential between a fluid pressure within the drive line and a fluid pressure within the at least one hydraulic cylinder.

2. The coiled tubing injector of claim **1**, where the reactive chain tension circuit includes:

a first valve configured to maintain the fluid pressure within the at least one hydraulic cylinder above a first pressure threshold; and

a second valve configured to maintain the fluid pressure within the at least one hydraulic cylinder below a second pressure threshold.

3. The coiled tubing injector of claim **2**, wherein the reactive chain tension circuit includes a pilot line connecting the first valve and the second valve in parallel to the drive line to provide the first valve and the second valve with a pressure signal indicative of a tubing load on the coiled tubing injector.

4. The coiled tubing injector of claim **3**, wherein the at least one hydraulic motor includes a first port in fluid communication with the drive line and the pilot line.

5. The coiled tubing injector of claim **4**, wherein the tension system includes an auxiliary fluid source; and wherein the first valve is configured to maintain the fluid pressure within the at least one hydraulic cylinder above the first pressure threshold by selectively connecting the auxiliary fluid source to the at least one hydraulic cylinder based on the pressure signal.

6. The coiled tubing injector of claim **5**, wherein the first valve is connected to the auxiliary fluid source with an auxiliary line including an adjustable orifice operable to control a fluid flow rate between the auxiliary fluid source and the reactive chain tension circuit.

7. The coiled tubing injector of claim **5**, wherein the first valve and the second valve are connected to the reactive chain tension circuit by a tension line, the tension line including a two-way valve operable to disconnect the reactive chain tension circuit from the tension system.

8. The coiled tubing injector of claim **7**, wherein the first valve and the second valve are connected to each other via an intermediary line extending therebetween, the intermediary line including a directional control valve positioned to prevent fluid flow from the tension line to the first valve to reduce leakage associated with the at least one hydraulic cylinder; and wherein the tension line is connected to the intermediary line between the directional control valve and the second valve.

9. The coiled tubing injector of claim **8**, wherein the second valve is configured to maintain the fluid pressure within the at least one hydraulic cylinder below the second pressure threshold by selectively connecting the tension line to a discharge line.

10. The coiled tubing injector of claim **9**, further comprising an external fluid source connected to the at least one hydraulic cylinder, wherein the external fluid source is manually operable to increase the fluid pressure within the at least one hydraulic cylinder to the second pressure threshold or decrease the fluid pressure within the at least one hydraulic cylinder to the first pressure threshold.

11. A coiled tubing injector comprising:

two or more drive chains each forming a continuous loop and carrying a plurality of grippers for engaging coiled tubing within a grip zone defined between the two or more drive chains;

a drive system including:

a first drive sprocket engaged with a first drive chain of the two or more drive chains;

a second drive sprocket engaged with a second drive chain of the two or more drive chains;

a first hydraulic motor for turning the first drive sprocket;

a second hydraulic motor for turning the second drive sprocket, wherein the first hydraulic motor and the second hydraulic motor are connected in parallel to a drive line and a return line forming a drive circuit for fluidly powering the first hydraulic motor and the second hydraulic motor; and

a tension system including:

one or more first hydraulic cylinders for tensioning the first drive chain;

one or more second hydraulic cylinders for tensioning the second drive chain; and

a reactive chain tension circuit for automatically tensioning the first drive chain and the second drive chain by maintaining a pressure differential between a fluid pressure within the drive line and a fluid pressure within the first hydraulic cylinder and the second hydraulic cylinder, wherein the reactive chain tension circuit is connected to a first port of the first hydraulic motor via a pilot line to provide the reactive chain tension circuit with a pressure signal indicative of a tubing load on the coiled tubing injector.

12. The coiled tubing injector of claim **11**, wherein the reactive chain tension circuit includes:

a flow divider configured to maintain the fluid pressure within the first hydraulic cylinder and the second hydraulic cylinder above a first pressure threshold; and

a pilot operated pressure control valve configured to maintain the fluid pressure within the first hydraulic cylinder and the second hydraulic cylinder below a second pressure threshold, wherein the pilot line connects the flow divider and the pilot operated pressure control valve to the drive line in parallel.

13. The coiled tubing injector of claim **12**, wherein the pilot line includes a pressure reducing valve configured to limit a maximum fluid pressure at the flow divider and the pilot operated pressure control valve.

14. The coiled tubing injector of claim **13**, wherein the pilot line includes an adjustable orifice operable to control a fluid flow rate between the first hydraulic motor and the pressure reducing valve; and wherein the reactive chain tension circuit includes a two-way valve operable to disconnect the reactive chain tension circuit from the drive line.

15. A method of using a coiled tubing injector including two or more drive chains carrying a plurality of grippers for engaging coiled tubing within a grip zone defined between a first drive chain and a second drive chain, and a drive system for turning the two or more drive chains and including at least one hydraulic motor connected to a drive line for fluidly powering the at least one hydraulic motor, the method comprising:

activating the drive system to begin moving the coiled tubing through the grip zone toward a wellbore; and

tensioning the two or more drive chains by a reactive chain tension circuit based on a fluid pressure within the at least one hydraulic motor, by maintaining a pressure differential between the fluid pressure within the at least one hydraulic motor and a fluid pressure within at least one hydraulic cylinder for tensioning the first drive chain and the second drive chain.

16. The method of claim **15**, wherein tensioning the two or more drive chains by the reactive chain tension circuit includes:

actuating a first valve to maintain a fluid pressure within the reactive chain tension circuit above a first pressure threshold; and

actuating a second valve to maintain the fluid pressure within the reactive chain tension circuit below a second pressure threshold.

17. The method of claim **15**, wherein tensioning the two or more drive chains by the reactive chain tension circuit includes:

directing hydraulic fluid through a flow divider to maintain a fluid pressure within the reactive chain tension circuit above a first pressure threshold; and

actuating a pilot operated pressure control valve to maintain the fluid pressure within the reactive chain tension circuit below a second pressure threshold.

18. The method of claim **17**, wherein directing hydraulic fluid through a flow divider to maintain a fluid pressure within the reactive chain tension circuit above a first pressure threshold includes actuating a pressure reducing valve to limit a fluid pressure at the flow divider and the pilot operated pressure control valve.

19. The method of claim **15**, wherein tensioning the two or more drive chains by the reactive chain tension circuit includes first adjusting an orifice between the reactive chain tension circuit and the drive line.

20. The method of claim **15**, wherein tensioning the two or more drive chains by the reactive chain tension circuit includes first connecting the reactive chain tension circuit to the at least one hydraulic motor.

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